A COMPARISON OF THE COMPRESSIVE STRENGTH AND SHRINKAGE OF PORTLAND CEMENT-FLY ASH CONCRETE WITH THE CHEMICAL CONSTITUENTS OF THE FLY ASH

by

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INTRODUCTION

Concrete is a term generally associated with "portland cement concrete" although there are other cements and other concretes. The term cement as used herein will be restricted to a powdered mineral which can be mixed with water to form a plastic mass and which hardens chemically by gel and crystal formation and by combination rather than by vitrification, cooling, or drying. In addition to the portland cements such materials as lime, gypsum, pozzolans in the presence of lime, natural cement, alumina cement and plastic magnesia fall under this definition. (5)

Cements may be placed under two broad classifications—non-hydraulic and hydraulic. Hydraulic cements have the ability to harden under water. Until the development of natural cements within the last two centuries the only hydraulic cementing materials used were those composed of a mixture of pozzolan and lime. Pozzolans were used extensively by the ancient Romans and Egyptians in all types of masonry construction. The Roman Pantheon, the Coliseum, the Basilica of Constantine, the Pont du Gard, and many other structures were constructed with pozzolanic mixtures; some have survived to the present day.

Under the Romans the art of using concrete was highly developed even by today's standards. Many of the problems in the use of concrete mentioned by the Romans have not been solved to this day. (2) After the Romans the art of concrete usage suffered a long period of retrogression that was especially noticeable during the Middle Ages. The poor quality of the mortars used during the Middle Ages was at least partly due to carelessness in handling, incomplete burning of the lime, and the absence of pozzolanic material in the cements. (2)

With the advent of the eighteenth century science appeared to have a surge of growth. The curiosity of many chemists, engineers, and professors was directed toward the mystery of cement. Communications were very poor so that discoveries made in France or Holland might be completely unknown in England; this led to a considerable duplication of effort. Eventually in 1756, John Smeaton, an English engineer, discovered a process for the manufacture of natural cement whereas the Romans had used materials fully prepared except for the addition of lime. Smeaton found that impure limestone when calcined and ground had hydraulic properties. The mortar used was hydraulic lime.

The important advances in Smeaton's work over the Roman art was his recognition that impurities (clayey material) in the natural limestone accounted for the hydraulic properties and his use of calcination and the grinding of the calcined product. Roman cements were largely manufactured by nature (volcanic action); Smeaton made possible the use of a manufactured cement. Smeaton narrowly missed the discovery of portland cement for three general reasons:

1. Reliance was placed on natural proportioning rather than controlled artifical proportioning.
2. The calcining temperature employed was low; vitrification or incipient fusion did not occur.
3. The hard-burned particles were discarded as worthless; these actually make the best cement. (5)

Natural cement is defined (ASTM C 10-37) as: "...the product obtained by finely pulverizing calcined argillaceous limestone, to which not to exceed five per cent of non-deleterious materials may be added subsequent to calcination. The temperature of calcination shall be no higher than is necessary to drive off carbonic acid gas." Natural cement is not as uniform, as strong, and is slower setting than portland cement.

Sixty-eight years later (1824) Joseph Aspdin, a brick-layer of Leeds, England, recognized the advantages to be gained from artificial proportioning and harder burning. His work led to the patenting of a process for the manufacture of "Portland Cement" so-called because of its resemblance to limestone on Portland Island.

Portland cement has always conformed to one general definition but Aspdin's "portland" cement probably had little resemblance to the cement of today. The basic definition of portland cement is: "...the product obtained by finely pulverizing clinker produced by calcining to incipient fusion an intimate and properly proportioned mixture of argillaceous and calcareous materials, with no additions subsequent to calcination excepting water and calcined or uncalcined gypsum."

Allowing no additions other than gypsum subsequent to calcination was calculated to produce a standardized product. The implication that any such addition was harmful or non-beneficial was inherent in the specification.

As reinforced concrete became more and more popular as a building material, a need was developed for a code of practice for both plain and reinforced concrete. This led to the formation in 1904 of the First Joint Committee on Specifications for Concrete and Reinforced Concrete. The final report of this committee (published in 1916) provided a pattern for concrete practice throughout the United States. Eventually both second and third joint committees were formed with their final reports being issued in 1924 and 1940, respectively. Much of the initiative in reporting concrete research has been assumed by the American Concrete Institute (ACI). The American Society for Testing Materials (ASTM) through its committees C 1 on Cement and C 9 on Concrete and Concrete Aggregates is constantly publicizing research and standardizing practice. The Portland Cement Association (PCA) has also contributed by research in its own and in cooperating laboratories.

By the late 1930's cement manufacturers found that small amounts of tallow or resinous material added to the clinker aided final grinding and did no visible harm to the cement. A clause added at that time to the portland cement specification by the ASTM Committee C 1 provided for certain additions within given maximum amounts. Further research showed that slightly larger amounts of resinous or greasy materials ground with the clinker gave air-entrained properties to the cement. Air-entrained concretes had greater plasticity (even with less water), more freedom from segregation, and increased durability against freezing and thawing and against damage from the salts used in snow removal. (4)

The initial ASTM standard for portland cement was adopted in 1904 as C 9-04. Revisions were made in 1908, 1909, 1916, 1920, 1926, 1930, 1937, and 1938. During this time a need developed for other types of portland cements such as high-early-strength and sulfate resisting cements. Such varied demands led in 1940 to ASTM C 150 which recognized five separate types of portland cement. There are now three separate ASTM specifications for portland cement—C 150, C 175, and C 205—each of which is composed of two or more subtypes.

Considerable interest has since developed in the use of pozzolan-portland cement concretes. In particular, the use of fly ash in concrete has been the subject of a large amount of research. Many fly ashes are highly pozzolanic; they are not cements by themselves but have the ability to combine with the free lime of the cement to form insoluble cementitious compounds. (4)

Fly ash is the finely divided residue from powdered coal which is caught in electric precipitators in steam power plants. Most city ordinances require that a high percentage of the fly ash be collected. Disposal is a problem of considerable magnitude with the annual collection in the United States estimated in excess of 4,000,000 tons. A productive use of fly ash in concrete would be of great value to cement users and to producers of fly ash. Cement users view fly ash as an inexpensive replacement for cement in concrete and as a replacement which adds beneficial qualities to the concrete.

The use of fly ash will generally result either in no change in the quantity of mixing water required or in some cases will permit a small reduction for a given slump. Fly ash concrete places more readily with less vibration required. The surface may be darker with some fly ashes than ordinary portland cement concrete. Properly proportioned fly ash concrete may have early strengths which are slightly less than those of ordinary concrete; after a period of a few months the fly ash mixtures will be stronger. Permeability will be reduced by adding fly ash to the cement, the heat of hydration will be lower, cement-aggregate reaction will be reduced, and resistance to attack by most acids increased. (4) (5).

To aid in evaluating the performance of a fly ash the American Society for Testing Materials is proposing a specification for fly ash for use as an admixture for portland cement concrete. The members of the committees concerned have been unable to agree in principle on a specification whose use would result in a uniform product. This is at least partly due to the variation in the chemical constituents of the fly ashes. Fly ash is produced in a large number of plants from a variety of coals burned in many different ways; as a result fly ashes vary widely in their physical and chemical properties. To meet the specifications a fly ash would have definite limits on the maximum and minimum percentages of its chemical constituents.

OBJECTIVE

The objective of this research was to correlate the compressive strength and the shrinkage of various fly ash concretes with the chemical constituents of the fly ash. There are many tests used to evaluate the physical properties of concrete but the compressive strength and the shrinkage tests are regarded as being among the most reliable.

TEST PROCEDURE

Compressive Strength

1. The standard method of test for the compressive strength of hydraulic-cement mortars (ASTM Designation: C 109-44) was used. Two types of portland cement (Type I and Type II) were used with each of twelve different fly ashes. The mix proportions were:

525 grams cement
175 grams fly ash
1925 grams Ottawa sand

A control mix consisting of 700 grams of cement and 1925 grams of Ottawa sand was made for each of the two types of cement.

2. Six 2-inch cubes were made in each mix. Immediately after molding the test specimens were placed in the moist closet for 24 hours. After 24

hours the specimens were removed from the molds and immersed in clean water which was held at a constant temperature of 70° F.

3. A hydraulic testing machine was used for the compressive tests. Tests were made on three of the cubes at 7 and 28 days. The compressive strength was calculated in pounds per square inch.

Shrinkage

1. The test specimens used in the shrinkage tests were 1 by 1-inch with an effective gage length of 10 inches. A metal insert used as a reference point was placed in each end of the specimen. Thirty-eight mixes were made using nineteen different fly ashes. The two mix proportions were as follows:

(a) 262.5 grams cement

$$\frac{175 \times \text{sp. gr. fly ash}}{\text{sp. gr. cement}} = \text{grams fly ash}$$

$$962 - \frac{87.5 \times \text{sp. gr. sand}}{\text{sp. gr. cement}} = \text{grams Ottawa sand}$$

(b) 262.5 grams cement

$$\frac{87.5 \times \text{sp. gr. fly ash}}{\text{sp. gr. cement}} = \text{grams fly ash}$$

962 grams Ottawa sand

2. Three of the test specimens were made for each mix. Immediately after molding the specimens were placed in the moist closet for 24 hours. After 24 hours they were removed from the molds and immersed in clean water at 70° F. for 6 days. The specimens were then removed from the water and cured in laboratory air which was maintained at 72° F. and 55% relative humidity.

3. A dial gage comparator capable of measuring to the nearest ten-thousandth of an inch was used for the shrinkage readings. Readings were taken at 30, 60, 90, and 180 days. Those readings taken at 60 days were

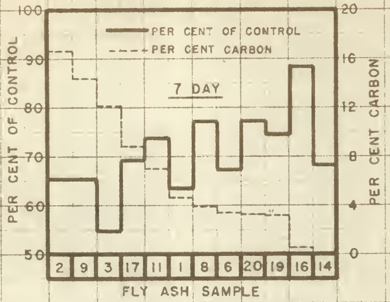
chosen for comparison since it was found that with such small bars most of the shrinkage had taken place by then.

Comparison of Results

The 7-day and the 28-day compressive strengths and the 60-day shrinkages were compared with the percentages of carbon, silicon dioxide (SiO_2), ferric oxide (Fe_2O_3), aluminum oxide (Al_2O_3), and sulfur trioxide (SO_3). The compressive strengths were evaluated by expressing the strength of each mix as a percentage of the strength of the control mix at the same age.

Table 1. Chemical analysis of twenty fly ash samples.

Sample:	% SiO_2:	% Al_2O_3:	% Fe_2O_3:	% SO_3:	% Carbon
1	44.17	28.65	17.28	0.39	4.67
2	39.74	27.17	12.29	0.57	16.72
3	36.46	25.34	19.01	0.54	12.05
4	47.44	30.39	13.89	0.23	3.98
5	41.75	25.09	6.62	0.54	18.18
6	49.53	26.92	10.75	0.28	3.60
7	38.98	26.24	15.46	1.18	6.84
8	34.01	20.15	26.43	1.34	3.96
9	36.31	27.05	18.08	0.49	14.32
10	35.95	23.13	22.67	1.24	5.41
11	43.22	27.92	15.89	0.38	7.09
12	47.32	27.61	9.64	0.43	8.70
13	46.54	19.67	18.20	2.81	0.89
14	41.76	17.50	18.49	3.59	—
15	45.45	17.60	20.03	2.73	0.82
16	47.54	20.81	19.22	2.26	0.59
17	43.94	22.58	19.62	0.46	8.87
18	47.71	28.73	10.63	0.60	5.95
19	43.72	22.22	22.87	0.76	3.36
20	44.39	25.22	18.35	0.55	3.52



MIX DATA FOR NINE 2x2 CUBES

525 GRAMS TYPE I CEMENT
175 GRAMS FLY ASH
1925 GRAMS OTTAWA SAND

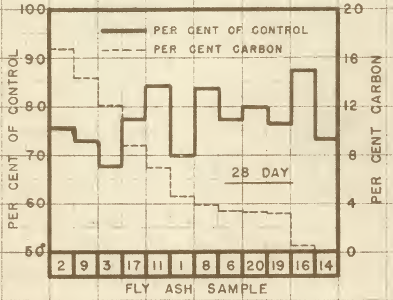
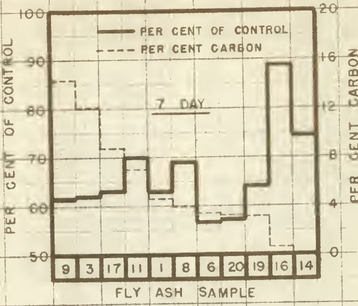


FIG. 1 A COMPARISON OF COMPRESSIVE STRENGTH IN 70° WATER WITH PER CENT CARBON (TYPE I CEMENT)



MIX DATA FOR NINE 2x2 CUBES
525 GRAMS TYPE II CEMENT
175 GRAMS FLY ASH
1925 GRAMS OTTAWA SAND

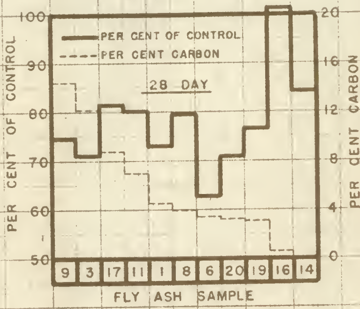
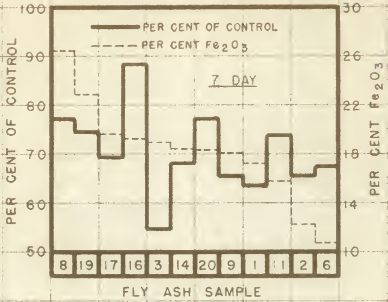


FIG. 2 A COMPARISON OF COMPRESSIVE STRENGTH IN 70° WATER WITH PER CENT CARBON (TYPE II CEMENT)



MIX DATA FOR NINE 2 x 2 CUBES
525 GRAMS TYPE 1 CEMENT
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1925 GRAMS OTTAWA SAND

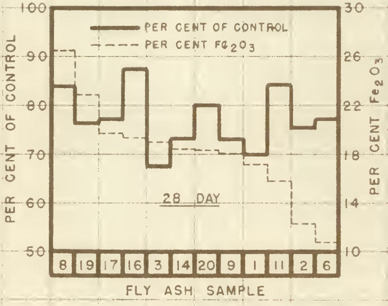
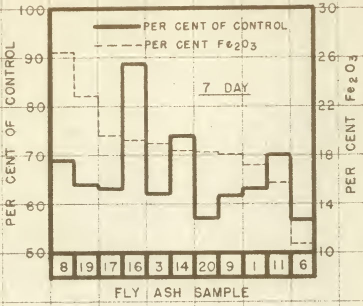


FIG. 3 A COMPARISON OF COMPRESSIVE STRENGTH IN 70° WATER WITH PER CENT Fe_2O_3 (TYPE 1 CEMENT)



MIX DATA FOR NINE 2 x 2 CUBES
525 GRAMS TYPE II CEMENT
175 GRAMS FLY ASH
1925 GRAMS OTTAWA SAND

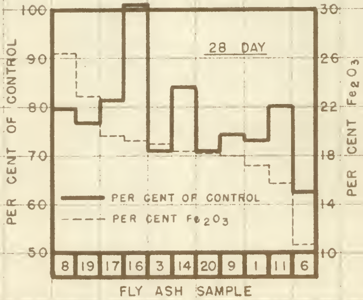
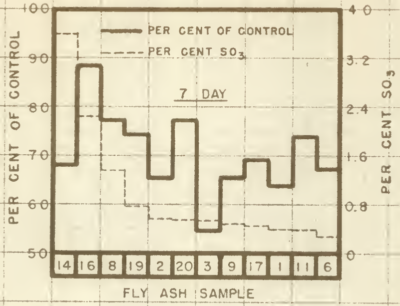


FIG. 4 A COMPARISON OF COMPRESSIVE STRENGTH IN 70° WATER WITH PER CENT Fe_2O_3 (TYPE II CEMENT)



MIX DATA FOR NINE 2 x 2 CUBES
525 GRAMS TYPE I CEMENT
175 GRAMS FLY ASH
1925 GRAMS OTTAWA SAND

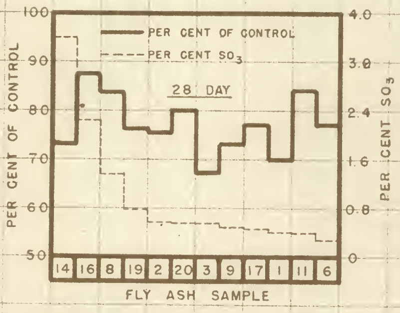


FIG. 5 A COMPARISON OF COMPRESSIVE STRENGTH IN 70° WATER WITH PER CENT SO_3 (TYPE I CEMENT)

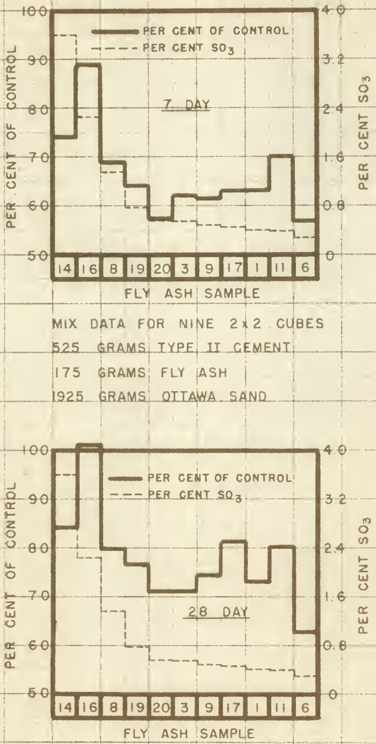
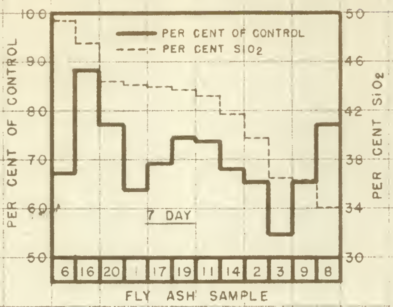


FIG. 6 A COMPARISON OF COMPRESSIVE STRENGTH IN 70° WATER WITH PER CENT SO_3 (TYPE II CEMENT)



MIX DATA FOR NINE 2 x 2 CUBES

525 GRAMS TYPE I CEMENT

175 GRAMS FLY ASH

1925 GRAMS OTTAWA SAND

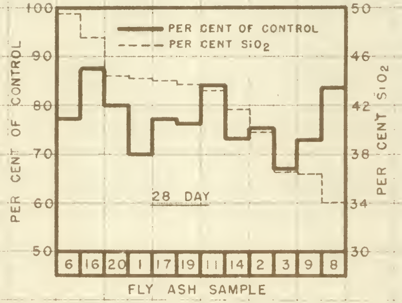
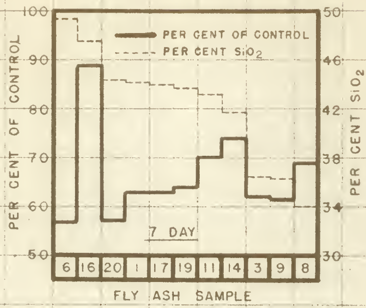


FIG. 7 A COMPARISON OF COMPRESSIVE STRENGTH IN 70° WATER WITH PER CENT SiO_2 (TYPE I CEMENT)



MIX DATA FOR NINE 2 x 2 CUBES
525 GRAMS TYPE II CEMENT
175 GRAMS FLY ASH
1925 GRAMS OTTAWA SAND

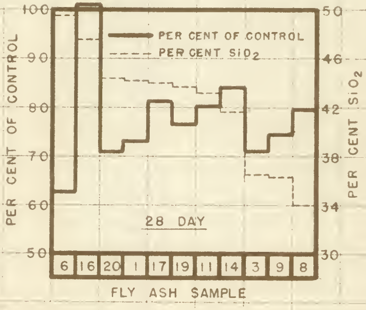
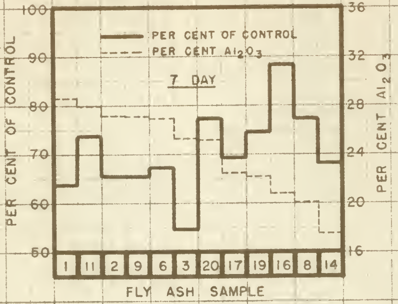


FIG. 8 A COMPARISON OF COMPRESSIVE STRENGTH IN 70° WATER WITH PER CENT SiO_2 (TYPE II CEMENT)



MIX DATA FOR NINE 2 x 2 CUBES

525 GRAMS TYPE I CEMENT

175 GRAMS FLY ASH

1925 GRAMS OTTAWA SAND

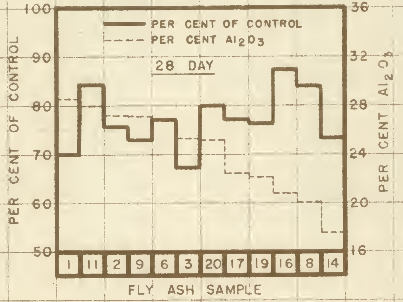
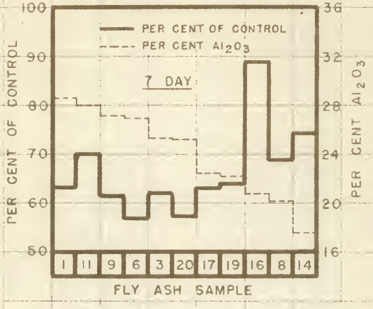


FIG. 9 A COMPARISON OF COMPRESSIVE STRENGTH IN 70° WATER WITH PER CENT Al_2O_3 (TYPE I CEMENT)



MIX DATA FOR NINE 2 x 2 CUBES
525 GRAMS TYPE II CEMENT
175 GRAMS FLY ASH
1925 GRAMS OTTAWA SAND

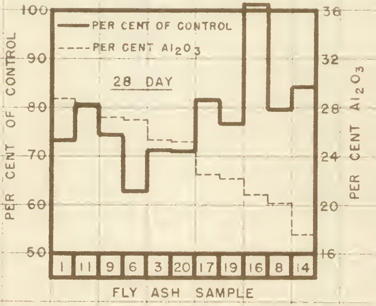


FIG. 10 A COMPARISON OF COMPRESSIVE STRENGTH IN 70° WATER WITH PER CENT Al_2O_3 (TYPE II CEMENT)

MIX DATA FOR THREE 1x1x11 BARS

262.5 GRAMS STANDARD CEMENT

$$175 \times \frac{\text{SP. GR. FLY ASH}}{\text{SP. GR. CEMENT}} = \text{GRAMS OF FLY ASH}$$

$$962 - \frac{87.5 \times \text{SP. GR. SAND}}{\text{SP. GR. CEMENT}} = \text{GRAMS OTTAWA SAND}$$

CURING: 24 HRS. IN M.R. FOLLOWED BY 6 DAYS SOAKING

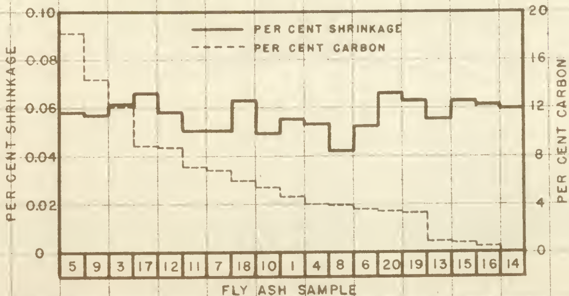


FIG. 11 A COMPARISON OF SHRINKAGE IN LABORATORY AIR WITH PER CENT CARBON (AGE 60 DAYS)

MIX DATA FOR THREE 1x1x11 BARS

262.5 GRAMS STANDARD CEMENT

$$87.5 \times \frac{\text{SP. GR. FLY ASH}}{\text{SP. GR. CEMENT}} = \text{GRAMS OF FLY ASH}$$

962 GRAMS OF OTTAWA SAND

CURING: 24 HRS. IN M.R. FOLLOWED BY 6 DAYS SOAKING

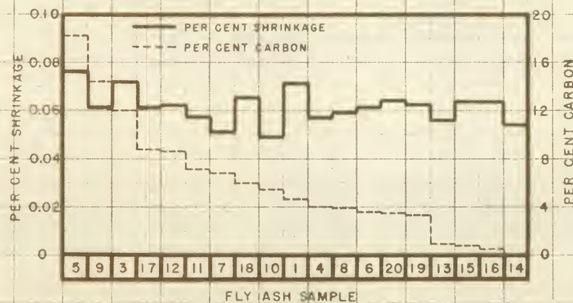


FIG.12 A COMPARISON OF SHRINKAGE IN LABORATORY AIR WITH PER CENT CARBON (AGE 60 DAYS)

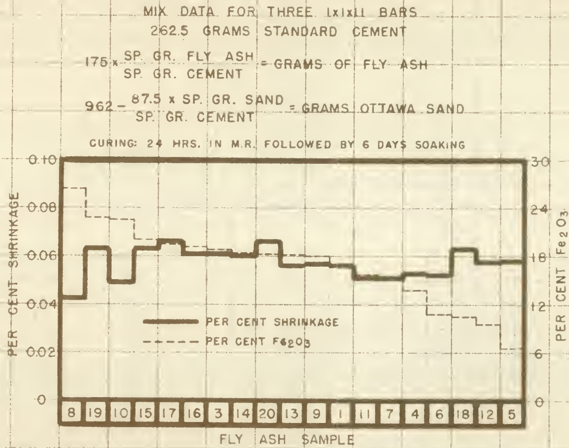


FIG. 13 A COMPARISON OF SHRINKAGE IN LABORATORY AIR WITH PER CENT Fe_2O_3 (AGE 60 DAYS)

MIX DATA FOR THREE 1x1x11 BARS

262.5 GRAMS STANDARD CEMENT

$87.5 \times \frac{\text{SP. GR. FLY ASH}}{\text{SP. GR. CEMENT}} = \text{GRAMS OF FLY ASH}$

962 GRAMS OF OTTAWA SAND

CURING: 24 HRS. IN M.R. FOLLOWED BY 6 DAYS SOAKING

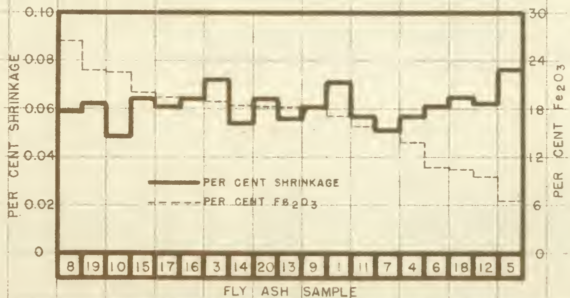


FIG. 14 A COMPARISON OF SHRINKAGE IN LABORATORY AIR WITH PER CENT Fe_2O_3 (AGE 60 DAYS)

MIX DATA FOR THREE 1x1x11 BARS

262.5 GRAMS STANDARD CEMENT

$$175 \times \frac{\text{SP. GR. FLY ASH}}{\text{SP. GR. CEMENT}} = \text{GRAMS OF FLY ASH}$$

$$962 - \frac{87.5 \times \text{SP. GR. SAND}}{\text{SP. GR. CEMENT}} = \text{GRAMS OTTAWA SAND}$$

CURING: 24 HRS. IN M.R. FOLLOWED BY 6 DAYS SOAKING

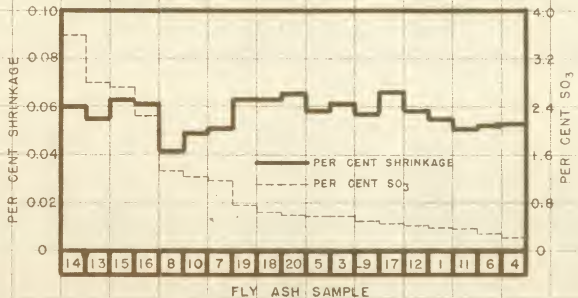


FIG.15 A COMPARISON OF SHRINKAGE IN LABORATORY AIR WITH PER CENT SO_3 (AGE 60 DAYS)

MIX DATA FOR THREE 1x1x11 BARS

262.5 GRAMS STANDARD CEMENT

$87.5 \times \frac{\text{SP. GR. FLY ASH}}{\text{SP. GR. CEMENT}} = \text{GRAMS OF FLY ASH}$

962 GRAMS OF OTTAWA SAND

CURING 24 HRS. IN M.R. FOLLOWED BY 6 DAYS SOAKING

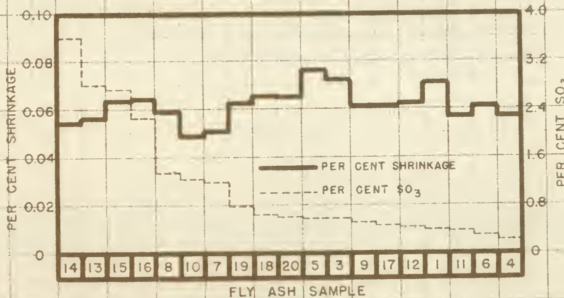


FIG. 16 A COMPARISON OF SHRINKAGE IN LABORATORY AIR WITH PER CENT SO_3 (AGE 60 DAYS)

MIX DATA FOR THREE 1x1x11 BARS

262.5 GRAMS STANDARD CEMENT

$$175 \times \frac{\text{SP. GR. FLY ASH}}{\text{SP. GR. CEMENT}} = \text{GRAMS OF FLY ASH}$$

$$962 - \frac{87.5 \times \text{SP. GR. SAND}}{\text{SP. GR. CEMENT}} = \text{GRAMS OTTAWA SAND}$$

CURING: 24 HRS. IN M.R. FOLLOWED BY 6 DAYS SOAKING

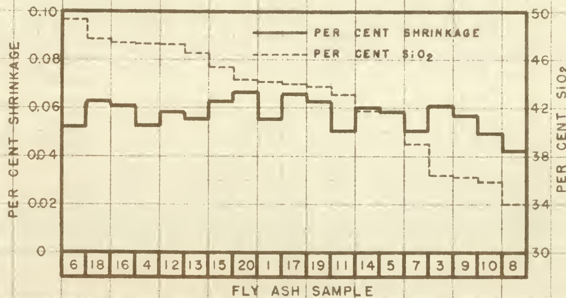


FIG. 17 A COMPARISON OF SHRINKAGE IN LABORATORY AIR WITH PER CENT SiO_2 (AGE 60 DAYS)

MIX DATA FOR THREE 1x1x11 BARS

262.5 GRAMS STANDARD CEMENT

$87.5 \times \frac{\text{SP. GR. FLY ASH}}{\text{SP. GR. CEMENT}}$ = GRAMS OF FLY ASH

962 GRAMS OF OTTAWA SAND

CURING: 24 HRS. IN M.R. FOLLOWED BY 6 DAYS SOAKING

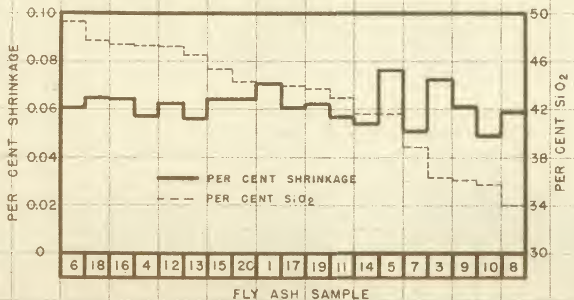


FIG.18 A COMPARISON OF SHRINKAGE IN LABORATORY AIR WITH PER CENT SiO_2 (AGE 60 DAYS)

MIX DATA FOR THREE 1x1x11 BARS

262.5 GRAMS STANDARD CEMENT

$$175 \times \frac{\text{SP. GR. FLY ASH}}{\text{SP. GR. CEMENT}} = \text{GRAMS OF FLY ASH}$$

$$962 - \frac{87.5 \times \text{SP. GR. SAND}}{\text{SP. GR. CEMENT}} = \text{GRAMS OTTAWA SAND}$$

CURING: 24 HRS. IN M.R. FOLLOWED BY 6 DAYS SOAKING

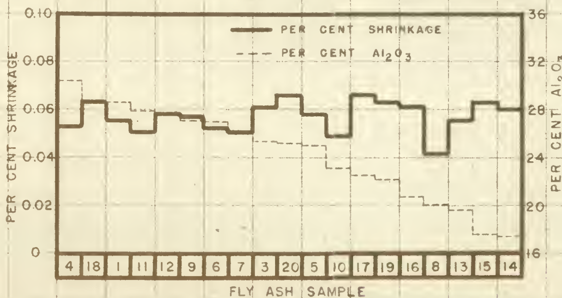


FIG. 19 A COMPARISON OF SHRINKAGE IN LABORATORY AIR WITH PER CENT Al_2O_3 (AGE 60 DAYS)

MIX DATA FOR THREE 1x1x11 BARS

262.5 GRAMS STANDARD CEMENT

$87.5 \times \frac{\text{SP. GR. FLY ASH}}{\text{SP. GR. CEMENT}}$ = GRAMS OF FLY ASH

962 GRAMS OF OTTAWA SAND

CURING: 24 HRS. IN M.R. FOLLOWED BY 6 DAYS SOAKING

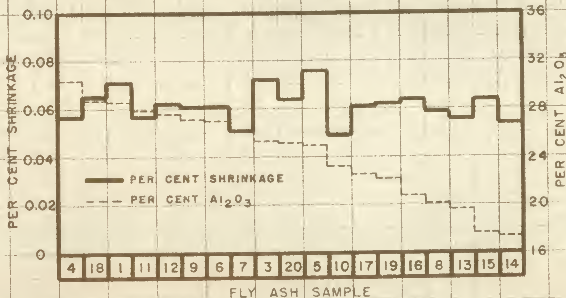


FIG.20 A COMPARISON OF SHRINKAGE IN LABORATORY AIR WITH PER CENT Al_2O_3 (AGE 60 DAYS)

DISCUSSION

The proposed tentative specifications for fly ash for use as an admixture for portland cement concrete now being considered by the ASTM contain definite limitations on the chemical and physical requirements of the material. For example, loss on ignition (represented for the most part by the carbon content) would be limited to a value somewhere between 5 and 12 percent. Sulfur trioxide (SO_3) would be limited to 4 percent; silicon dioxide (SiO_2) and aluminum oxide (Al_2O_3) would have minimum requirements of 30 and 10 per cent, respectively. The chemistry of cement hydration is a controversial subject; however, most authorities believe that the carbon content affects the compressive strength and the sulfur trioxide content affects the shrinkage.

Inspection of Figs. 1 to 20 does not reveal any definite variation in the compressive strength or the shrinkage with respect to any of the chemical constituents considered. The comparison of compressive strength to per cent carbon might be considered to show a slight trend (the less carbon the higher the compressive strength), but too many variations exist to form any definite conclusion for the number of samples tested.

Fly ash sample 16 gave the highest compressive strengths; samples 3 and 6 gave the lowest. A comparison of their chemical constituents follows:

	Sample 16	Sample 3	Sample 6
% Carbon	0.59	12.05	3.60
% Fe_2O_3	19.22	19.01	10.75
% SO_3	2.26	0.54	0.28
% SiO_2	47.54	36.46	49.53
% Al_2O_3	20.81	25.34	26.92

Writing a specification with limitations on the percentages of the chemical constituents for these three samples would be difficult.

Further inspection for Figs. 11 to 20 shows that variation in the chemical constituents of the fly ash apparently had little effect on the shrinkage of the concrete.

CONCLUSIONS

The satisfactory performance of many structures that have been built using fly ash as an admixture for the portland cement concrete indicates that fly ash is an economical and valuable additive. The author believes that the use of fly ash as an additive should be encouraged within the limits of safety and economy. However, a restrictive specification that placed stringent limitations on the chemical composition of the fly ash would discourage its use which in turn would limit the knowledge to be gained from observation of portland cement-fly ash concrete structures. As practical experience is gained the specifications could be made more restrictive if necessary in order to improve the performance of the finished concrete. It should also be pointed out that the mortar specimens made from fly ash-portland cement may not necessarily prove to be satisfactory criteria for judging expected field performance.

Therefore, since it is difficult to correlate the physical performance of a portland cement-fly ash concrete to any specific percentage of a chemical constituent of the fly ash, the author believes that initial specifications should be lenient until more practical experience with the material can be gained.

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REFERENCES

1. Blanks, R. F.
Fly ash as a pozzolan. Proc. A.C.I., vol. 46, 701-707, 1950

2. Bogue, R. H.
The chemistry of portland cement. New York: Reinhold Publishing Corporation, 1947

3. Davis, R. E.
Properties of cements and concrete containing fly ash. Jour. A.C.I., vol. 8, 577-612, May-June 1937

4. Davis, R. E.
Use of pozzolans in concrete. Proc. A.C.I., vol. 46, 377-384, 1950

5. Gilkey, H. J.
Cement and concrete. Civil Eng. Handbook, New York: McGraw-Hill, 1950

6. Scholer, C. H. and Smith, G. M.
Use of Chicago fly ash in reducing cement-aggregate reaction. Jour. A.C.I., vol. 23, 457-464, Feb. 1952

7. Symposium on the chemistry of cements. Stockholm: 1938

A COMPARISON OF THE COMPRESSIVE STRENGTH AND SHRINKAGE OF PORTLAND CEMENT-FLY ASH CONCRETE WITH THE CHEMICAL CONSTITUENTS OF THE FLY ASH

by

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B. S., University of Nebraska, 1949

ABSTRACT OF THESIS

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The American Society for Testing Materials sets up specifications for building materials and for methods of testing those materials that are considered as standards throughout the United States. At the present time the ASTM is considering tentative specifications for fly ash for use as an admixture for portland cement concrete. The tentative specification would limit the percentages of the chemical constituents of the fly ash to fixed amounts. The purpose of this research was to attempt to correlate the chemical constituents of the fly ash with two of the physical properties of portland cement-fly ash concrete—compressive strength and shrinkage. These two properties were chosen for comparison because they are considered among the most reliable methods for evaluating concrete performance.

The test procedures used followed the standard methods of test of the ASTM. The compressive strength was measured by means of 2 by 2-inch cubes and the shrinkage was observed on 1 by 1 by 10-inch bars.

The results of the tests were shown pictorially by means of graphs. Analysis of the graphs showed little or no correlation between the chemical constituents of the fly ash and the compressive strength and shrinkage of the portland cement-fly ash mortars. If this analysis is verified by further research it would indicate that restriction of the percentages of the chemical constituents of the fly ash to narrow limits might be misleading and unnecessary.